The Conical Fit Approach to Modeling Ionospheric Total Electron Content

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The Global Positioning System (GPS) can be used to measure the integrated electron density along raypaths between satellites and receivers. Such measurements may, in turn, be used to construct regional and global maps of the ionospheric *total electron content* (TEC). Maps are generated by fitting measurements to an assumed ionospheric model. The problem is inherently four-dimensional: each slant TEC measurement depends upon the position and orientation of its raypath. For example, if we define the *ionospheric pierce point* (IPP) of a raypath to be the point where the raypath intersects a reference ionospheric height, we can treat slant TEC measurements as functions of four parameters: the sublatitude and sublongitude of the IPP and the raypath azimuth and elevation angles at the IPP.

Current slant TEC models often simplify the problem by reducing its dimensionality. A typical strategy is to associate a given slant GPS measurement with the vertical TEC value at the IPP. The slant-to-vertical conversion (*i.e.*, the *mapping function*) is treated as a known function of elevation angle and other model variables. Two types of error restrict the accuracy of such models: (1) error associated with the choice of model mapping function, and (2) error arising from the neglect of horizontal gradients of the electron density along the raypath. Defining a mapping function requires assuming a predetermined form for the unknown height variation of the electron density profile. For example, the popular *thin-shell* model relies on the rather crude assumption that the electron density is non-negligible only in the vicinity of the ionospheric reference height. A consequence of the neglect of horizontal density gradients is that distinct measurements, which share a common IPP, can produce inconsistent estimates of the same vertical TEC value. Even should such estimates prove to be in agreement, they can still be in error due to an incorrect choice of ionospheric reference height.

This paper describes an alternative model of slant TEC measurements that retains the full four-dimensional character of the problem. The key to this approach is to obtain distinct sets of fit parameters for groups of measurements that each share a single satellite or a single receiver. For example, consider a set of measurements from a group of receivers that are all looking at the same satellite. The raypaths of these measurements define a cone whose vertex is the position of the satellite (hence, we designate our approach to be a *conical fit*). Fit parameters are retrieved for a cone assuming linear deviations of the electron density from local spherical symmetry. Maps of vertical TEC over a specified region may be generated by first solving for fit parameters associated with multiple cones, each with a different receiver or satellite at its vertex. Note that the fit for any individual cone is strictly a two dimensional problem: since one endpoint of each raypath is fixed, only two parameters are required to specify a measurement. Only when multiple cones are fit simultaneously does the four-dimensional nature of the problem reemerge.

We present results comparing the accuracy of this approach with that achieved using the thin-shell model. The accuracy of each approach is assessed using a *missing-measurement analysis*, *i.e.*, the value of a measurements excluded from the fit is compared to the value predicted by the model. We assess accuracy using data sets from both quiet days and days when the ionospheric is disturbed. Furthermore, we assess the dependency of accuracy on latitude by comparing results based upon data sets from Brazil and the United States.